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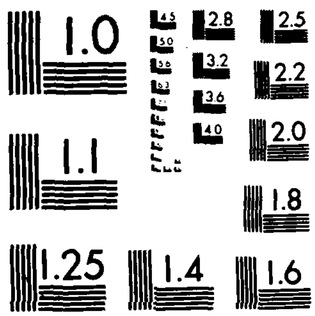
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The research activities of the Applied Mathematics Group during the first nine months of 1983 are described in this report. A brief outline of the research is presented. This is followed by a list of publication status of the work, and the abstracts of papers submitted for publication during this period.

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Applied Mathematics Group
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PROGRESS REPORT *for*

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The research activities of the Applied Mathematics Group during the first nine months of 1983 are described in this report. In the next section a brief outline of the research is presented. This is followed by a list of publication status of the work, and the abstracts of papers submitted for publication during this period.

Joseph B Keller

Joseph B. Keller Principal Investigator

Brief Outline of Research Findings

Section II of this report indicates the publication status of the research work of members of the Applied Mathematics Group. A number of papers previously accepted have been published, others previously submitted have been accepted, and a number of new ones have been submitted.

Among the latter are two papers by Professor Keller and his former student Dr. Kevin C. Nunan. They calculated the effective elastic behaviour of a composite of rigid spheres located at lattice points in an elastic matrix. They also calculated the effective viscosity of a similar arrangement of rigid spheres in a viscous fluid. The novelty of this work is that it covers all concentrations from zero to close packing.

Professors Geer and Keller completed their work on the eigenvalues of slender cavities, which provides a simple method for calculating such eigenvalues accurately. Their results agreed very well with previous numerical calculations for prolate spheroids.

Dr. Margaret Cheney has completed two new works on inverse scattering in two dimensions. This provides a further step towards making inverse scattering theory applicable to real physical problems.

II. PUBLICATIONS OF APPLIED MATHEMATICS GROUP

50.	J. B. Keller	Optimum inspection policies Pub: Management Sci., 28, 447-450, 1982.
51.	P. S. Hagan	Travelling and stacked travelling wave solutions of parabolic equations Pub: SIAM J. Math. Anal., 13, 717-738, 1982.
52.	J.-M. Vanden-Broeck	Contact problems involving the flow past an inflated aerofoil Pub: J. Appl. Mech., 49, 263-265, 1982.
53.	J.-M. Vanden-Broeck	Nonlinar two-dimensional sail theory Pub: Phys. Fluids, 25, 420-423, 1982.
55.	P. S. Hagan	Spiral waves in reaction diffusion equations Pub: SIAM J. Appl. Math., 42, 762-786, 1982.
56.	J.-M. Vanden-Broeck J. B. Keller	Parabolic approximations for ship waves and wave resistance Pub: Proceedings of the Third International Conference on Numerical Ship Hydrodynamics, Paris, France, June 16-19, 1981.
57.	A. Jeffrey T. Kawahara	Asymptotic Methods in Nonlinear Wave Problems Pub: Pitman Publishing, Ltd., London, 1982.
58.	M. J. Miksis J.-M. Vanden-Broeck J. B. Keller	Rising Bubbles Pub: J. Fluid Mech., 123, 31-42, 1982.
59.	J. C. Neu	Resonantly interacting waves Pub: SIAM J. Appl. Math., 43, I, 141-156, 1983.
60.	J. B. Keller M. J. Miksis	Surface tension driven flows Pub: SIAM J. Appl. Math., 43, II, 268-277, 1983.
61.	A. Jepson A. Spence	Folds in solutions of two parameter systems and their calculation: Part I Pub: Stanford Univ. Numer. Anal. Report, 82-02.

62. J. B. Keller — Time-dependent queues

Pub: SIAM Rev., 24, 401-412, 1982.

63. R. E. Caflisch, B. Nicolaenko — Shock profile solutions of the Boltzmann equation

Pub: Comm. Math. Phys., 86, 161-194, 1982.

64. P. S. Hagan, R. E. Caflisch, J. B. Keller — Arrow's model of optimal pricing, use and exploration of undertain natural resources

Sub: Econometrica

65. R. E. Caflisch — Radiation transport in a hot plasma

Acc: SIAM J. Appl. Math., in press.

66. J. B. Keller, J.-M. Vanden-Broeck — Jets rising and falling under gravity

Pub: J. Fluid Mech., 124, 335-345, 1982.

67. R. E. Caflisch — Fluid dynamics and the Boltzmann equation

Pub: Stud. Stat. Mech., 5, 194-223, 1983.

68.* M. S. Falkovitz, M Seul, H. L. Frisch, H. M. McConnell — Theory of periodic structures in lipid bilayer membranes

Pub: Proc. Nat. Acad. Sci., 79, 3918, 1982.

69. R. E. Caflisch — The fluid-dynamic limit of a model Boltzmann equation in the presence of a shock

Pub: Institute National de Recherche en Informatique et en Automatique, INRIA No. 81, June 1981, 1-34.

70. P. F. Rhodes-Robinson — On the short surface waves due to half-immersed circular cylinder oscillating on water of infinite depth

Pub: Proc. Royal Soc. London A, 384, 333-357, 1982.

71. P. F. Rhodes-Robinson — Note on the reflexion of water waves at a wall in the presence of surface tension

Pub: Math. Proc. Cambridge Philosophical Soc., 92, 369-373, 1982.

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*Not supported by AFOSR or ONR.

72. P. F. Rhodes-Robinson — On the generation of water waves at an inertial surface

Acc: J. Australian Math. Soc. B, in press.

73. R. E. Caflisch, G. C. Papanicolaou — Dynamic theory of suspensions with Brownian effects

Acc: SIAM J. Appl. Math., in press.

74. R. E. Caflisch, G. C. Papanicolaou — Instability in settling of suspensions due to Brownian effects

Pub: Proceedings of conference Two-Phase Flow.

75. R. E. Caflisch, B. Nicolaenko — Shock waves and the Boltzmann equation

Pub: Proceedings NSF-AMS conference non-linear PDE.

76. J. H. Maddocks — Restricted quadratic forms and their application to bifurcation and stability in constrained variational principles

Sub: SIAM J. Appl. Math.

77. M. S. Falkovitz, L. A. Segel — Spatially inhomogeneous polymerization in unstirred bulk

Pub: SIAM J. Appl. Math., 43, 386-416, 1983.

78. M. S. Falkovitz, J. L. Frisch — The scale of non-homogeneity as defined by diffusion measurements

Pub: Journal of Membrane Science, 10, 61, 1982.

79. M. S. Falkovitz, H. L. Frisch, J. B. Keller — Optimal catalyst distribution in a membrane

Acc: Chem. Eng. Sci., in press.

80.* M. S. Falkovitz, J. B. Keller — Crawling of Worms

Acc: J. Theor. Biol., in press.

81. A. Jeffrey, J. Mvungi — The random choice method and the free-surface water profile after the collapse of a dam wall

Pub: Wave Motion, 4, 381-389, 1982.

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*Not supported by AFOSR or ONR.

82. J. G. Watson, E. L. Reiss — A statistical theory for imperfect bifurcation

Pub: SIAM J. Appl. Math., 42, 135-148, 1982.

83. J. G. Watson, J. B. Keller — Reflection, scattering and absorption of acoustic waves by rough surfaces

Acc: J. Acoust. Soc. Am.

84. M. I. Weinstein — Global existence for a generalized Korteweg - de Vries equation

Sub: SIAM J. Math. Anal.

85. M. I. Weinstein — Nonlinear Schrödinger equations and sharp interpolation estimates

Pub: Commun. Math. Phys., 87, 567-576, 1983.

86. M. Cheney — Two-dimensional scattering: the number of bound states from scattering data

Sub: J. Math. Phys.

87. L. L. Bonilla, A. Liñán — Relaxation oscillations, pulses, and travelling waves in the diffusive Volterra delay-differential equation

Acc: SIAM J. Appl. Math., in press.

88. P. F. Rhodes-Robinson — Note on the effect of surface tension on water waves at an inertial surface

Pub: J. Fluid Mech., 125, 375-377, 1982.

89. J. B. Keller, J. Hunter — Weak shock diffraction

Acc: Wave Motion, in press.

90. J. B. Keller, J. Hunter — Weakly nonlinear high frequency waves

Pub: Comm. Pure Appl. Math., 36, 547-569, 1983.

91. J. B. Keller, J. C. Neu — Asymptotic analysis of a viscous Cochlear model

Sub: J. Acoust. Soc. Am.

92. J. B. Keller, J.-M. Vanden-Broeck — Parabolic approximations for ship waves and wave resistance

Pub: Proc. 3rd Intl. Conf. on Numerical Ship Hydrodynamics, Paris, France, June 16-19, 1981.

93. A. Spence, A. Jepson — The numerical computation of turning points of nonlinear equations

Pub: Treatment of Integral Equations by Numerical Methods, 169-183, London, 1982.

94. J. B. Keller, R. Burridge — Biot's poroelasticity equations by homogenization

Pub: Springer Lecture Notes, in Macroscopic Properties of Disordered Media, NY, 51-57,1982.

95. J. B. Keller — Capillary waves on a vertical jet

Acc: J. Fluid Mech., in press.

96. J. B. Keller, A. S. Whittemore — Survival estimation using censored data

Sub: J. Royal Statist. Soc., Series B

97. J. B. Keller, J. F. Geer — Eigenvalues of slender cavities and waves in slender tubes

Acc: J. Acoust. Soc. Am., in press.

98. J. B. Keller, R. Voronka — Valuation of stocks and options

To be submitted.

99. M. Cheney — Inverse scattering in dimension two

Acc: J. Math. Phys., in press.

100. K. C. Nunan, J. B. Keller — Effective viscosity of a periodic suspension

Sub: J. Fluid Mech.

101. K. C. Nunan, J. B. Keller — Effective elasticity Tensor of a Periodic Composite

Acc: J. Mech. Phys. Solids, in press.

102. J. B. Keller — Breaking of liquid films and threads

Acc: Phys. Fluids, in press.

103. J. B. Keller, G. R. Verma — Hanging rope of minimum elongation

Acc: SIAM Rev.

104.	M. Cheney S. Coen A. Weglein	Velocity & density of a two-dimensional acoustic medium from point source surface data <u>Sub</u>: Phys. Rev. Lett.
105.	J. B. Keller	Probability of a shutout in racquetball <u>Acc</u>: SIAM Rev.
106.	S. Venakides	The Zero Dispersion Limit of the Korteweg-de Vries Equation for Initial Potentials with Non-trivial Reflection Coefficient <u>Sub</u>: Comm. Pure Appl. Math.
107.	J. H. Maddocks	Stability of Nonlinearly Elastic Rods <u>Acc</u>: Arch. Rat. Mech. Anal., in press.
108.*	J. B. Keller	Genetic Variability Due to Geographical Inhomogeneity Sub: J. Math. Biol.
109.	J. B. Keller M. S. Falkovitz	Precipitation pattern formation In preparation.

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III. ABSTRACTS OF MANUSCRIPTS SUBMITTED OVER REPORT PERIOD

1. WEAK SHOCK DIFFRACTION, by J. Hunter and J.B. Keller.

The diffraction of a weak shock by a rigid wedge is analyzed theoretically via the theory of weakly nonlinear geometrical acoustics, which is the same as Whitham's nonlinearization technique. First linear and weakly nonlinear geometrical acoustics are explained. Then the linear acoustics results for weak shock diffraction by a wedge are presented. Next these results are modified according to the principles of weakly nonlinear geometrical acoustics. The results show that the compressive diffracted wavefronts of linear acoustics are actually shocks, and their positions and strengths are found. The infinite gradients of the linear acoustics rarefaction waves are found to be finite but discontinuous gradients. Finally the results are specialized to a shock hitting a right-angled wedge, a shock coming off a right-angled wedge, and a shock hitting a thin semi-infinite screen.

2. WEAKLY NONLINEAR HIGH FREQUENCY WAVES, by J. Hunter and J.B. Keller.

We shall present a method for finding small-amplitude, high-frequency wave solutions of hyperbolic systems of quasilinear partial differential equations. The method applies in any number of space dimensions, and reduces to "geometrical optics" when the equations are linear. Therefore we call it *weakly nonlinear geometrical optics.*

The method yields the first terms in an asymptotic expansion of a solution with respect to a small parameter ε. This parameter is a measure of both the amplitude and the period of a wave. The solution consists of a slowly varying mean and a superposition of small-amplitude, high-frequency waves. Each of these waves undergoes distortion due to nonlinear selfinteraction. When the distortion leads to multi-valuedness, shocks are introduced to maintain single-valuedness. For conservative systems, the shock locations are found to obey an equal area rule. The interaction among the various waves is a higher-order effect which is negligible unless a certain resonance condition holds. The present method does not apply in the resonant case.

3. CAPILLARY WAVES ON A VERTICAL JET, by J.B.Keller.

Geer and Strikwerda devised a slender jet theory for a jet falling vertically, with surface tension present. They solved the resulting problem numerically by extending a method they had developed previously. Their results showed that the cross-section of the jet decreased in area and oscillated in shape with distance along the jet. They compared the oscillations with Rayleigh's results for oscillations of a jet of constant circular cross-section. There was agreement qualitatively but not quantitatively.

We shall analyze the oscillations of a vertically falling jet on the basis of their theory in order to obtain a quantitative description of them which agrees with the numerical

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results. First we find the solution for a vertical jet with a circular cross-section. Then we determine its small amplitude oscillations. Our analysis differs from Rayleigh's because our unperturbed jet is falling, so its velocity and radius are not constant.

4. SURVIVAL ESTIMATION WITH CENSORED DATA, by A. Whittemore and J.B. Keller.

New nonparametric methods are given for estimating survival probability using randomly right-censored data. A class of estimators is obtained by the maximum likelihood method, in which the hazard rate is approximated by a suitably chosen spline function. The class includes the estimator proposed by Nelson (1969) and Altshuler (1970). The estimators are shown to be uniformly consistent and to have the same asymptotic weak convergence properties as the Kaplan-Meier estimator. In small and in heavily censored samples, new estimators in the class have uniformly smaller mean squared error than do the Kaplan-Meier (1958) and Nelson-Altshuler estimators, according to computer s[illegible]lations. The methods are extended to provide new estimates for both the baseline [illegible]ard rate and the regression coefficients in the proportional hazards model proposed by [illegible] (1972). Several existing estimates for these quantities, including that obtained using [illegible] partial likelihood, occur as special cases of the general procedure. The methods ar[illegible]rated using experimental carcinogenesis data.

5. EFFECTIVE VISCOSITY OF A PERIODIC SUSPENSION, by K.Nunan and J.B. Keller

The effective viscosity of a suspension is defined to be the four-tensor which relates the average deviatoric stress to the average rate of strain. We determine the effective viscosity of an array of spheres centered on the points of a periodic lattice in an incompressible Newtonian fluid. The formulation involves the traction exerted on a single sphere by the fluid, and an integral equation for this traction is derived. For lattices with cubic symmetry the effective viscosity tensor involves just two parameters. They are computed numerically for simple, body-centered and face-centered cubic lattices of spheres with solute concentrations up to 90% of the close-packing concentration. Asymptotic results for high concentrations are obtained for arbitrary lattice geometries, and found to be in good agreement with the numerical results for cubic lattices. The low concentration asymptotic expansions of Zuzovsky also agree well with the numerical results.

6. THE ZERO DISPERSION LIMIT OF THE KORTEWEG-DE VRIES EQUATION FOR INITIAL POTENTIALS WITH NON-TRIVIAL REFLECTION COEFFICIENT, by S. Venakides.

The inverse scattering method is used to determine the distribution limit as $\varepsilon \to 0$ of the solution $u(x,t,\varepsilon)$ of the initial value problem:

$$u_t - 6uu_x + \varepsilon^2 u_{xxx} = 0$$

$$u(x,0) = v(x)$$

where $v(x)$ is a positive bump which decays sufficiently fast as $x \to \pm\infty$. The case $v(x) \leq 0$ has been solved by Peter D. Lax and C.D. Levermore.

The computation of the distribution limit of $u(x,t,\varepsilon)$ as $\varepsilon \to 0$ is reduced to a quadratic maximization problem.

7. VELOCITY AND DENSITY OF A TWO-DIMENSIONAL ACOUSTIC MEDIUM FROM POINT SOURCE SURFACE DATA, by S. Coen, Margaret Cheney and A. Weglein.

An inverse acoustic scattering theory and algorithm is presented for the reconstruction of a two dimensional inhomogeneous acoustic medium from surface measurements. The measurements of the surface pressure due to a harmonically oscillating surface point source at two arbitrary frequencies allows the separate reconstruction of the density and velocity of the subsurface. This is a first step towards solving the inverse problem of exploration geophysics.

8. GENETIC VARIABILITY DUE TO GEOGRAPHICAL INHOMOGENEITY, by J.B. Keller.

The frequency ratio of two alleles is studied as a function of position and time, in a two-dimensional region, by means of a nonlinear diffusion equation. Each allele is assumed to have a selective advantage in some part of the region. An asymptotic solution is constructed when the selection coefficient is large compared to the diffusion coefficient, *i.e.*, when selection acts more rapidly than diffusion. As time increases, the solution tends to an equilibrium distribution in which both alleles are present everywhere, each predominating where it has the advantage.